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The Age of Peak Marathon Performance in Cross-Country Skiing – The 'Engadin Ski Marathon'

Running head: Age of peak cross-country skiing performance

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ABSTRACT

The age of the best endurance performance has been well investigated in flat city running marathons. However, we have no knowledge about the age of peak marathon performance in cross-country skiing, which would be of great practical value for athletes and coaches. Therefore, the aim of the present study was to examine the age of peak marathon performance in cross-country skiing. Participants were 162,991 men and 34,833 women competing between 1998 and 2016 in the 'Engadin Ski Marathon'. We considered for both women and men the fastest and all finishers in 1-year age intervals. The men-to-women ratio increased across ages (r^2=0.55, P<0.0001). Men (44.27±0.03 years, 15.73±0.01 km/h) were 5.98±0.07 years older and 2.14±0.02 km/h faster (P<0.0001) than women (38.29±0.06 years, 13.58±0.01 km/h). Considering the fastest participants in 1-year age intervals, the fastest speed for men (30.33 km/h) was achieved at the age of 29 years and for women (28.76 km/h) at the age of 24 years. Considering all participants, the fastest speed for men (17.69 km/h) was observed at the age of 18 years, whereas for women (15.76 km/h) at the age of 17 years. In summary, for athletes and coaches, the age of peak performance in cross-country skiers competing in a marathon distance was much younger and closer to the peak of aerobic capacity than what was found by previous studies in marathon road runners.

Key Words: women; men; long-distance performance

INTRODUCTION

Cross-country skiing, one of the earliest known winter physical activities (6), is a sport of high popularity especially in countries characterized by low temperatures and high snowfall, especially in Scandinavia (5). Cross-country skiing is a form of skiing where skiers rely on their own locomotion to move across snow-covered terrain. Skiers propel themselves either by striding forward (*i.e.* classic style) or side-to-side in a skating motion (*i.e.* skate skiing), aided by arms pushing on ski poles against the snow.

A main parameter that influences sport performance is the age of peak performance and every sports discipline has its specific age of peak performance (1, 9, 17). To the authors' knowledge, the age of peak performance has not been studied in cross-country skiing. Currently, the information for a possible age of peak performance in cross-country skiing is provided by different modes of exercise, such as running, with similar duration.

Considering marathon running, the age of peak marathon performance was reported between ~20 and ~50 years for both women and men depending upon the investigated races or data and the kind of analysis (9-14). Hunter et al. (9) analysed the five fastest men and women (*i.e.* peak running speed) in seven major marathon events. Women (29.8±4.2 years) were older than men (28.9±3.8 years), but for only two (*i.e.* Chicago Marathon and London Marathon) of the seven considered marathons (9). At the age of ~50 years both women and men showed a decline in running speed, which was more pronounced in women (14). Running speed showed no changes before the age of ~50 years in both marathoners and half-marathoners (14).

A statistical approach to determine the age of peak marathon performance is the use of non-linear regression analyses by considering race times in 1-year age intervals (13). When marathon race times of the top ten women and men aged from 18 to 75 years in the 'New York City Marathon' were analysed in 1-year age intervals for the 2010 and 2011 races, the fastest race times were obtained at ~27 years in men and at ~29 years in women (12). When the world single age records in marathon running were analysed in 1-year age intervals for women and men, performance was quite linear between ~20 and ~35 years, but started to decrease at the age of ~35 years in a curvilinear manner with increasing age in both women and men (10). In male marathoners competing from 1979 to 2014 in the 'Stockholm Marathon', the fastest performance was achieved at the age of ~34 years (13). The age of ~34 years remained unchanged when all men in 1-year age intervals were investigated and also the fastest men in 1-year-age-inverals (13).

The age of peak marathon performance has been well investigated for running. However, the age of peak marathon performance is not known for cross-country skiing, which might be of great practical importance for athletes and coaches in this sport. Also, it might be of theoretical importance for sport scientists focusing on the research of age group athletes as a model of successful aging. From a practical perspective, the knowledge of the age of peak performance in cross-country skiing might help coaches and athletes set realistic goals according to age and tailoring accordingly their training program. From a theoretical perspective, the study of the age of peak performance in cross-country skiing compared to other endurance events (*e.g.* running, cycling and swimming) might give insights into the association of aging and endurance exercise of various modes and physiological demands.

Therefore, the authors aimed to determine the age of peak marathon performance in cross-country skiing, and particularly, in the 'Engadin Ski Marathon' (Switzerland), which has been held since 1969 and whose distance was extended in 1998 to cover the exact marathon distance. By analyzing the race data from 1998 to 2016, and based upon the findings for marathon running the authors hypothesized that the age of peak performance in a cross-country marathon would be at a similar age of ~30-35 years for both women and men.

METHODS

Experimental Approach to the Problem

All procedures used in the study were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland with a waiver of the requirement for informed consent of the participants given the fact that the study involved the analysis of publicly available data.

Subjects

In this study, all athletes who finished the 'Engadin Ski Marathon' between 1998 and 2016 were considered. Data were obtained from the publicly available race website of the 'Engadin Skin Marathon' at www.engadin-skimarathon.ch.

The 'Engadin Ski Marathon' is an annually held cross-country ski race taking place on the second Sunday of March in the upper Engadin valley in Switzerland, Europe, between Maloja and S-chanf. The race originated in 1969, has been a part of the Worldloppet, and is one of the major cross-country skiing events in the Alps. Each year, between 11,000 and 13,000 skiers participate in this race. Since 1998, the total distance covered is 42 km. In that year, the race was extended by 2 km to match the distance of a full marathon and the track was changed slightly in the Stazerwald section, resulting in a more difficult topography, and longer race times are now standard. The track record of 1 h 16 min 10 s was set by Hervé Balland in 1994. In the same year, Silvia Honegger completed the race with the female track record of 1 h 22 min 08 s. While it is a freestyle race, there are separate tracks for skiers practicing classic style for all but the narrowest parts of the race. Participation is open to anyone from the age of 16 years, and no license is required to sign up.

The start of the race takes place in Maloja at the Maloja Palace Hotel with an elevation of 1,820 meters above sea level. The track leads over both Lake Sils and Lake Silvaplana which are both frozen at this time of year. After passing St. Moritz there is a forested climb in the Stazerwald. The proceeding descent to Pontresina is regarded by many as the most spectacular part of the race for spectators, due to the high number of falls and crashes by skiers. The race then follows the runway of Samedan Airport and afterwards continues on the right side of the Engadin valley, passing several small communities before reaching the finish in S-chanf at an elevation of 1,670 meters above sea level.

Data Analysis and Statistical Analyses

The men-to-women ratio was calculated with all men and all women for each age group, and the trend in the ratio across age groups was analysed using single linear regression analysis. Speed and age of women and men were compared using unpaired T-test. For the age of the best performance, we determined the non-linear regression model with a second order polynomial function ($y = a * x^2 + b * x + c$) that fits the data best since performance in marathon running seems to follow a quadratic (*i.e.*

second order polynomial) function (13). Since Lehto (13) found that for both the fastest men and all men in 1-year age intervals the age of the fastest marathon race time was the same, we determined for both women and men the fastest and all finishers in 1-year age intervals. The age of peak performance and the corresponding performance was determined by calculating the vertex of the quadratic function $p(x|y) = \left(-\frac{b}{2a} \middle| c - \frac{b^2}{4a}\right)$. Statistical analyses were performed using IBM SPSS Statistics (Version 22, IBM SPSS, Chicago, IL, USA). Significance was accepted at $P<0.05$ (two-sided for *t*-tests). Data in the text are given as mean ± standard deviation (SD).

RESULTS

Data from a total of 162,991 men and 34,833 women were available for analysis. Men were mainly participating between 35 and 45 years, women between 25 and 35 years with a second peak at ~40 years (Figure1). The men-to-women ratio increased highly significantly ($r^2=0.55$, $P<0.0001$) across ages (Figure 2).

Men (44.27±0.03 years) were 5.98±0.07 years older ($P<0.0001$) than women (38.29±0.06 years) (Figure 3). Men (15.73±0.01 km/h) were 2.14±0.02 km faster ($P<0.0001$) than women (13.58±0.01 km/h) (Figure 4).

Considering the fastest women and men in 1-year age intervals, the fastest speed for men (30.33 km/h) (Figure 5) was at the age of 29 years and for women (28.76 km/h) at the age of 24 years (Figure 6).When all men were considered, athletes at the age of 18 years were the fastest with 17.69±4.68 km/h (Figure 7). For all women, athletes at the age of 17 years were the fastest with 15.76±4.35 km/h (Figure 8).

DISCUSSION

This study determined the age of peak marathon performance in the Engadin Ski Marathon and hypothesized it would be similar to running marathons. The most important findings were (*i*) when the fastest skiers were considered, the fastest speed was achieved at the age of 29 years in men, but at 24 years in women, and (*ii*) when all skiers were considered, the fastest speed was achieved at 18 years in men and 17 years in women.

The fastest women and men in 1-year age intervals

A first important finding was that women (17 years) were at a similar age like men (18 years) when the fastest women and men were considered in 1-year age intervals. These ages are far below the reported ages of elite marathon runners achieving their best marathon race times at the age of ~29-30 years (9). A potential explanation could be that cross-country skiing is a highly technical discipline compared to running and younger athletes are better in a technical sport than older athletes. A further explanation could be that the overall race time is considerably faster in this skiing marathon than in a running marathon which might also enhance performance in younger athletes since it has been reported that older athletes preferably compete in longer race distances compared to younger athletes (1).

The different age of peak performance between marathon skiing and marathon running might be attributed to physiological factors (*e.g.* aerobic capacity, body composition and muscle strength), too. Both events rely mostly on the aerobic energy transfer system; thus, both marathon skiers and runners should possess high aerobic capacity (*i.e.* maximal oxygen uptake, VO_2max). However, compared to runners, skiers recruit their upper body in a larger degree, which might explain why cross-country skiers are the athletes that exhibit the highest values of VO_2max ever reported (6). For instance, VO_2max values for skiers that reach 80-90 $ml \cdot min^{-1} \cdot kg^{-1}$ in men and 70-80 $ml \cdot min^{-1} \cdot kg^{-1}$ in women (16). However, physiological parameters such as VO_2max do not fully explain the exercise economy in cross-country skiing (15).

Since cross-country skiing is a sport relying in VO_2max more than marathon running, it is reasonable to assume that the best skiers would be at an age closer to the biological peak of VO_2max than the marathon runners. It has been reported that the age of peak athletic performance is at the age of ~26 years when 25 Olympic sports events were analyzed (2). In addition to the discrepancy of age of peak performance between skiers and runners, the age-related variation of VO_2max might explain sex differences in the age of peak performance, *i.e.* earlier peak of VO_2max in women than in men. Moreover, there is evidence from a study on adolescent athletes that physiological correlates of performance might vary by sex (18). Performance in girls correlated mostly with aerobic capacity, whereas with upper body and trunk strength in boys. The relatively young age of peak performance in cross-country skiing compared to running marathon might be explained also by the age of peak muscle strength. In skiing, due to the intense use of upper body and trunk (165), a relatively larger amount of muscle strength is needed, which privileges the younger athletes.

Also, technical aspects should be considered, because by using an optimal technique the metabolic energy transforms into faster speed (16). Cross-country skiing has two basic propulsion techniques, the classic and the skate skiing technique (7, 8). While the classic technique relies on a wax or texture on the ski bottom under the foot for traction on the snow to allow the skier to slide the other ski forward in virgin or tracked snow, with the skate skiing technique the skier slides on alternating skis on a firm snow surface at an angle from each other in a manner similar to ice skating. Both techniques employ poles with baskets that allow the arms to participate in the propulsion. Both poles can be used simultaneously (*i.e.* double-poling), or alternating, in classic the alternating technique is most common (*i.e.* diagonal stride) while in the skating technique double poles are more common. The classic technique was used late into the Eighties in the last century and the skate skiing technique is relatively new. In the 'Engadin Ski Marathon', tracks for both techniques are available. It has been shown that the speed in the skate skiing technique is ~10-30% faster compared to the classic technique. A potential explanation could be that younger athletes learn the skate skiing technique easier than older athletes and/or several older athletes start cross-country skiing at a higher age (*i.e.* newcomer in this sport).

The aspect of drafting should also be considered. In a field of thousands of athletes, young and fast athletes may start very fast and other fast athletes may be able to follow in their slipstream. It has been shown that skiing behind another skier in a classical cross-country ski race is advantageous and can help racers using energy. This saved energy may help to achieve a faster mean speed during the whole race (3, 4).

All women and men in 1-year age intervals

A second important finding was that women (24 years) were ~5 years younger than men (29 years) when all women and men were considered in 1-year age intervals. The age of 29 years for men is ~5 years younger compared to the age of male marathoners competing from 1979 to 2014 in the 'Stockholm Marathon', where the fastest performance was achieved at the age of ~34 years (13). A likely explanation could be that Lehto (13) considered a longer time frame (1979-2014) and a higher number of subjects with 312,342 male runners.

Considering the cross-country skiers in this race, women competed preferably at a younger age (*i.e.* in their thirties) compared to men who competed preferably more in the forties. A further explanation could also be the age distribution between women and men. More women were competing in this race at ~25-35 years whereas men were preferably competing at the age of ~35-45 years. Moreover, the men-to-women ratio increased highly significantly across ages indicating that more men were competing at the higher ages compared to women.

Also the topography of the cross-country race could be a reason. When the age of peak marathon performance was compared between mountain and city marathon running, the fastest man in mountain marathon running was ~35.6 years and the fastest women ~34.5 years old when the fastest runners (11). When all finishers were considered, the fastest men were ~29.1 years old and the fastest women were ~25.6 years old. In city marathon running, the fastest man was ~23.7 years old and the fastest woman ~32.2 years old. When all finishers were considered in 1-year age intervals, the fastest men were ~35.0 years old and the fastest women ~33.8 years old (11). Obviously, in hilly terrain, younger athletes seemed to be at an advantage compared to flat terrain

Limitations

A limitation of the present study was that the findings on the age of peak performance in the cross-country skiing race under examination should be generalized with caution to other races. Each race has its own unique characteristics, such as elevations and environmental conditions (*e.g.* temperature and humidity), which influence performance.

PRACTICAL APPLICATIONS

In summary, the age of peak performance in cross-country skiers competing in a marathon distance was much younger and closer to the age of peak aerobic capacity than what was found by previous studies in marathon runners. Future studies need to examine the age of peak performance in cross-country skiing in shorter distances with regards to the age of peak running performance of the same distances. Strength of the study was the very large number of skiers that allowed drawing safe conclusions about the age of peak performance. This information is useful for researchers focusing on the study of master athletes as a model of successful aging. Since no previous study on this topic on cross-country skiing was ever conducted, the findings could be used in future studies as reference. Coaches and athletes can also benefit from such information, which help them develop sex- and age-tailored training programs.

REFERENCES

1. Allen SV and Hopkins WG. Age of peak competitive performance of elite athletes: A systematic review. *Sports Med* 45: 1431-1441, 2015.
2. Berthelot G, Len S, Hellard P, Tafflet M, Guillaume M, Vollmer JC, Gager B, Quinquis L, Marc A, and Toussaint JF. Exponential growth combined with exponential decline explains lifetime performance evolution in individual and human species. *Age (Dordr)* 34: 1001-1009, 2012.
3. Bilodeau B, Roy B, and Boulay MR. Effect of drafting on heart rate in cross-country skiing. *Med Sci Sports Exerc* 26: 637-641, 1994.

4. Bilodeau B, Roy B, and Boulay MR. Effect of drafting on work intensity in classical cross-country skiing. *Int J Sports Med* 16: 190-195, 1995.

5. Carlsson M, Assarsson H, and Carlsson T. The influence of sex, age, and race experience on pacing profiles during the 90 km Vasaloppet ski race. *Open Access J Sports Med* 7: 11-19, 2016.

6. Eisenman PA, Johnson SC, Bainbridge CN, and Zupan MF. Applied Physiology of Cross-Country Skiing. *Sports Med* 8: 67-79, 1989.

7. Hoffman MD. Physiological comparisons of cross-country skiing techniques. *Med Sci Sports Exerc* 24: 1023-1032, 1992.

8. Hoffman MD and Clifford PS. Physiological responses to different cross country skiing techniques on level terrain. *Med Sci Sports Exerc* 22: 841-848, 1990.

9. Hunter SK, Stevens AA, Magennis K, Skelton KW, and Fauth M. Is there a sex difference in the age of elite marathon runners? *Med Sci Sports Exerc* 43: 656-664, 2011.

10. Knechtle B, Assadi H, Lepers R, Rosemann T, and Rüst CA. Relationship between age and elite marathon race time in world single age records from 5 to 93 years. *BMC Sports Sci Med Rehabil* 6, 2015.

11. Knechtle B, Nikolaidis PT, Zingg MA, Rosemann T, Rüst CA. Differences in age of peak marathon performance between mountain and city marathon running - The ‘Jungfrau Marathon’ in Switzerland. *Chin J Physiol* 60: 11-22, 2017.

12. Lara B, Salinero JJ, and Del Coso J. The relationship between age and running time in elite marathoners is U-shaped. *Age (Dordr)* 36: 1003-1008, 2014.

13. Lehto N. Effects of age on marathon finishing time among male amateur runners in Stockholm Marathon 1979–2014. *J Sport Health Sci* 5: 349-354, 2015.

14. Leyk D, Erley O, Ridder D, Leurs M, Rüther T, Wunderlich M, Sievert A, Baum K, and Essfeld D. Age-related changes in marathon and half-marathon performances. *Int J Sports Med* 28: 513-517, 2007.

15. Losnegard T, Schäfer D, and Hallén J. Exercise economy in skiing and running. *Front Physiol.* 5:5, 2014

16. Sandbakk Ø and Holmberg HC. A reappraisal of success factors for olympic cross-country skiing. *Int J Sports Physiol Perform* 9: 117-121, 2014.

17. Schulz R and Curnow C. Peak performance and age among superathletes: Track and field, swimming, baseball, tennis, and golf. *J Gerontol* 43: P113-120, 1988.

18. Stöggl R, Müller E, and Stöggl T. Motor abilities and anthropometrics in youth cross-country skiing. *Scand J Med Sci Sports* 25: e70-e81, 2015.

FIGURE LEGENDS

Figure 1 The number of women and men in 1-year age intervals. The peak in participation was at a higher age in men compared to women.

Figure 2 The men-to-women ratio across 1-year age intervals with an increase with increasing age.

Figure 3 Box-Whisker-Plot (mean ± 95% confidence interval) for age in men and women

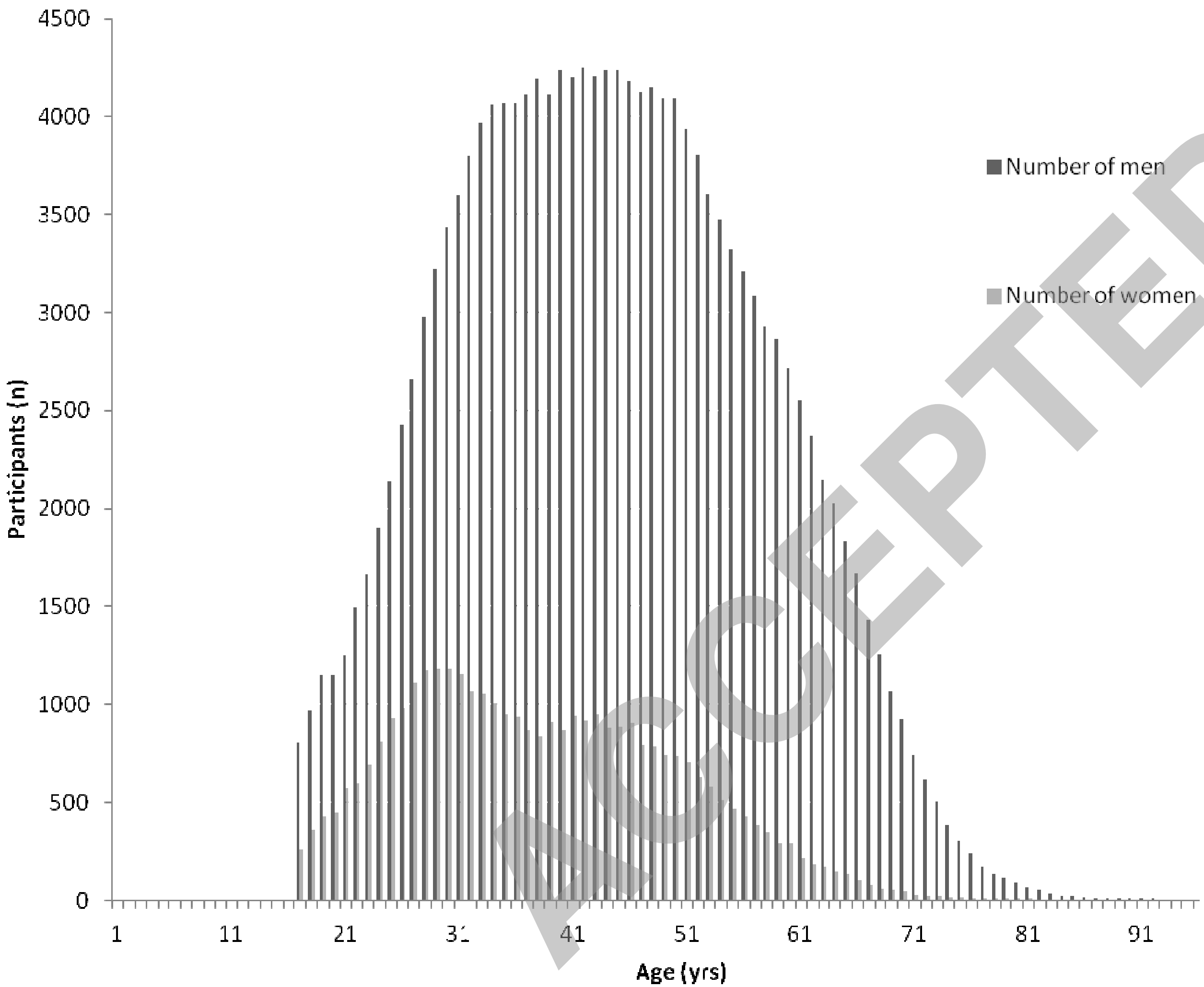
Figure 4 Box-Whisker-Plot (mean ± 95% confidence interval) for speed in men and women

Figure 5 The average speed of the fastest men as a function of age presented in 1-year age intervals

Figure 6 The average speed of the fastest women as a function of age presented in 1-year age intervals

Figure 7 The average speed of the fastest men as a function of age presented in 1-year age intervals. Data are presented as mean ± standard deviation.

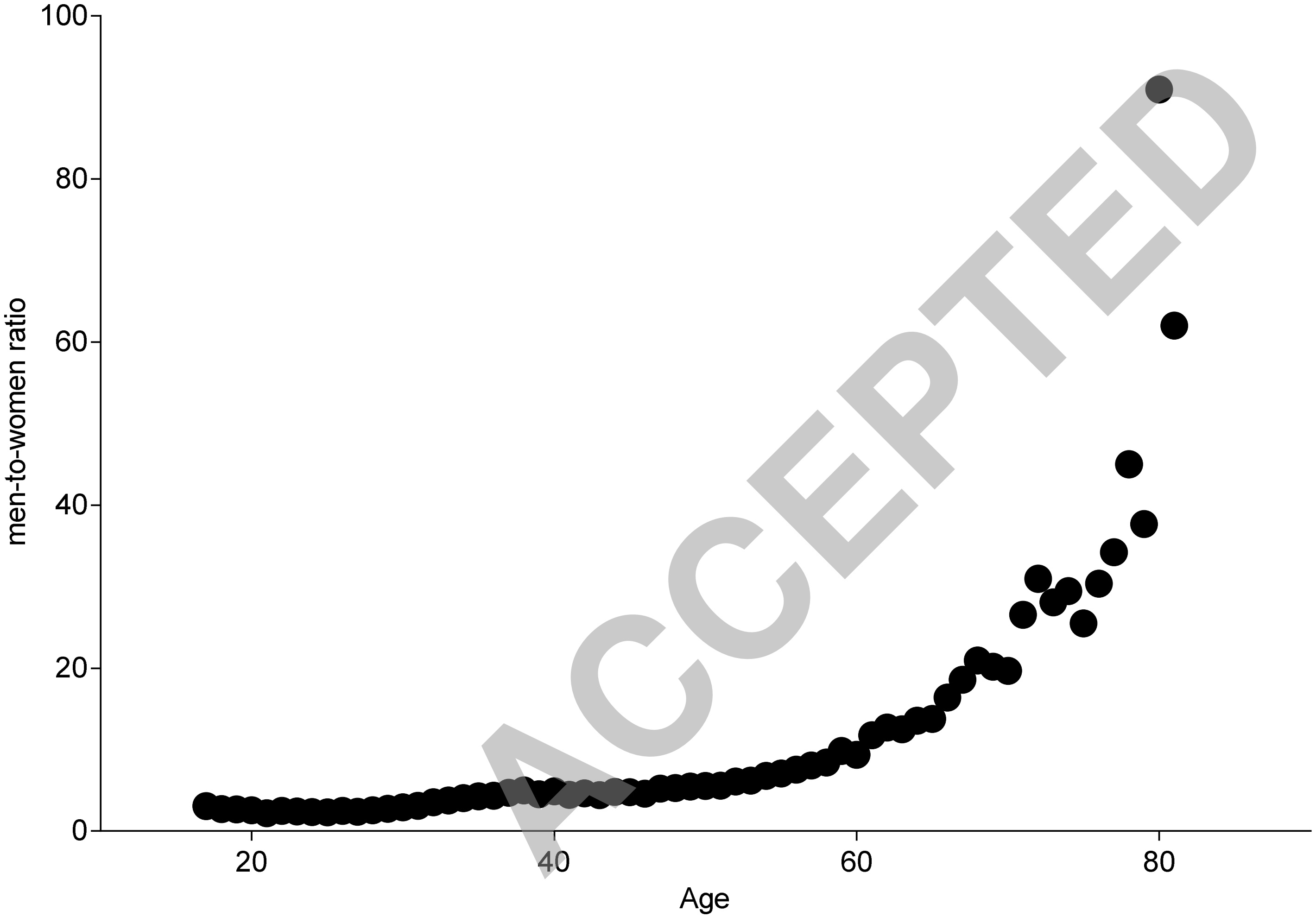
Figure 8 The average speed of the fastest women as a function of age presented in 1-year age intervals. Data are presented as mean ± standard deviation.



4500
4000
3500
3000
2500
2000
1500
1000
500
0
Participants (n)
Number of men
Number of women
1
11
21
41
51
61
71
81
91
Age (yrs)

Figure 1

396



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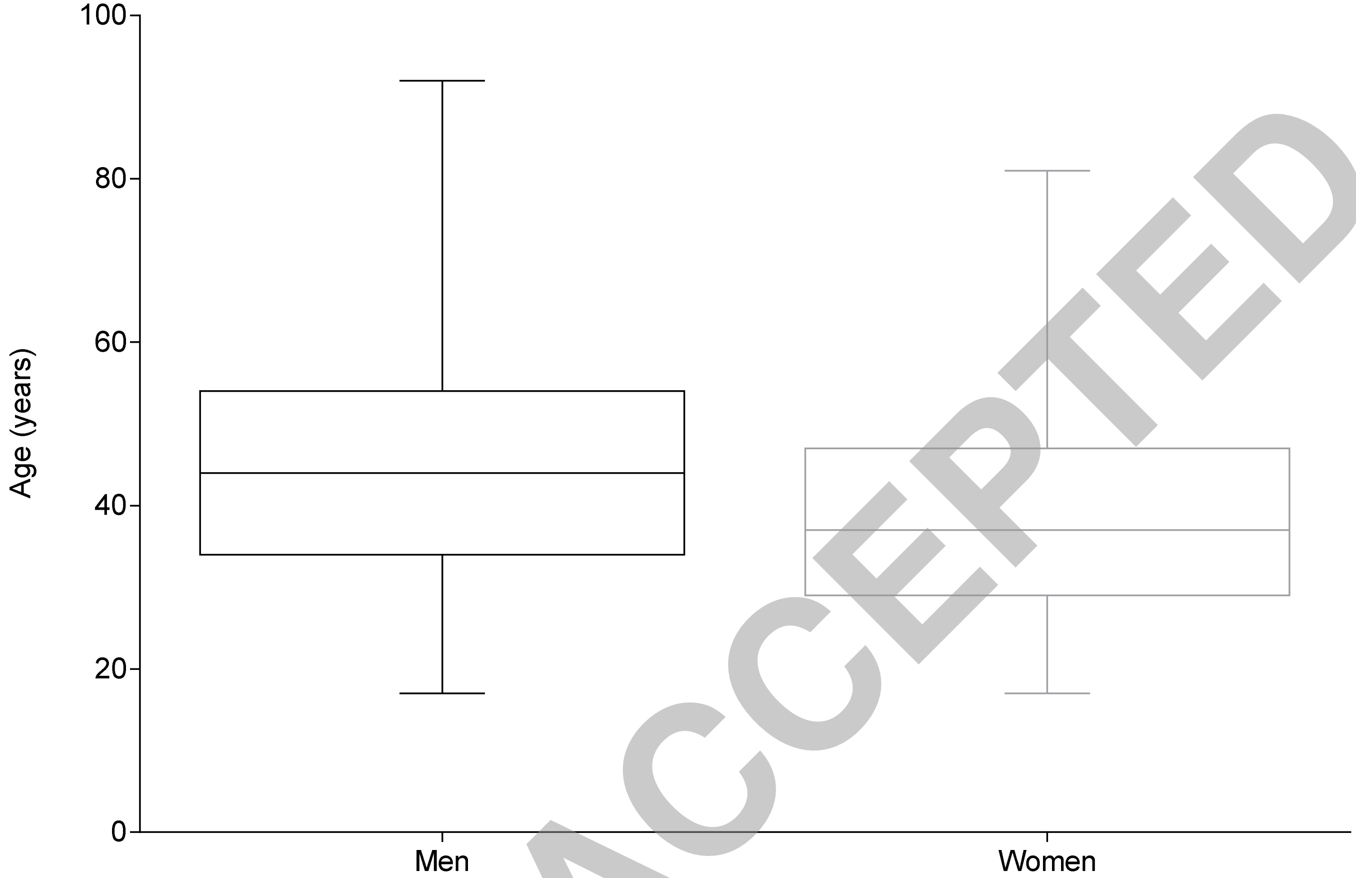


Figure 3

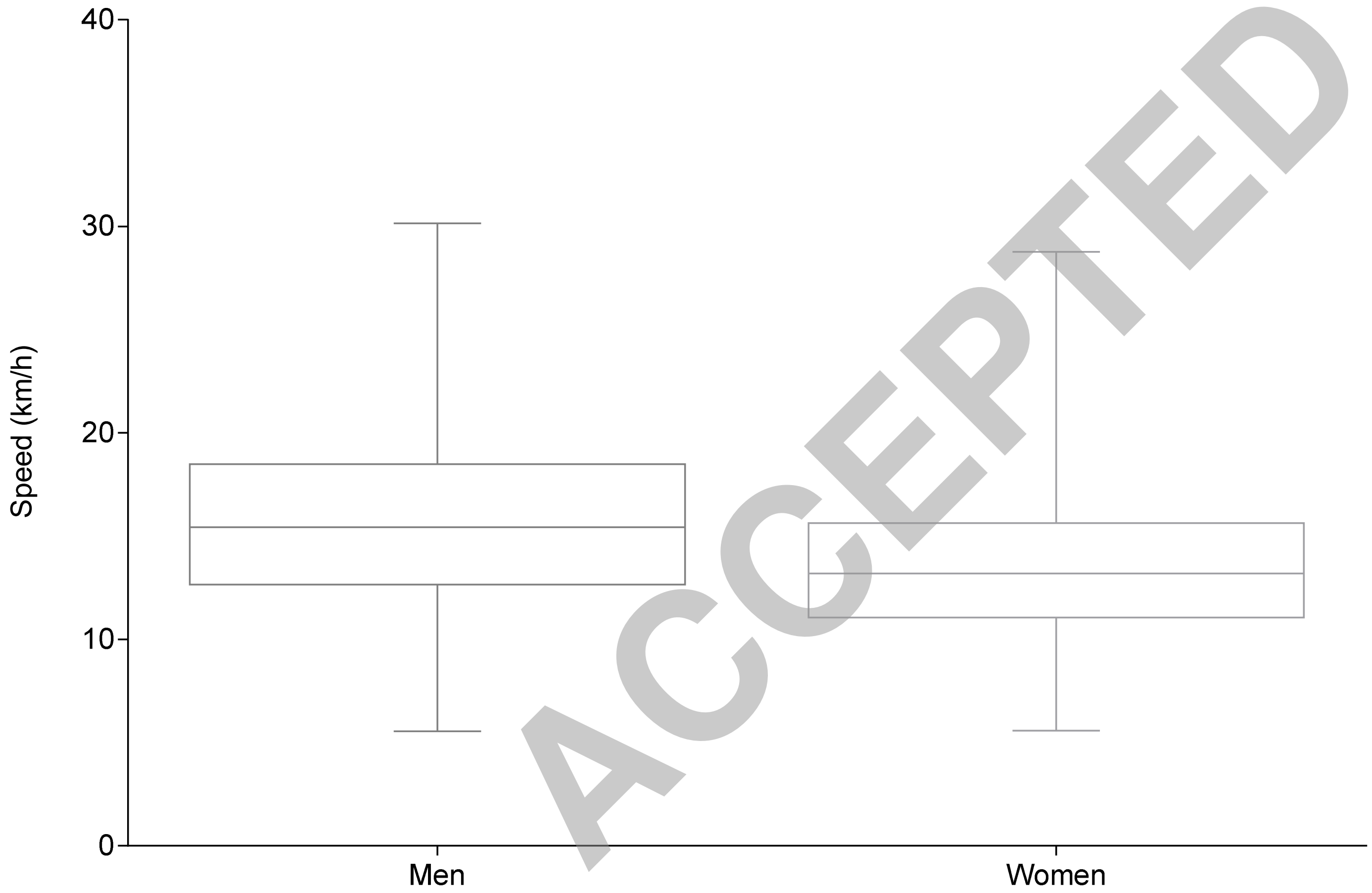


Figure 4

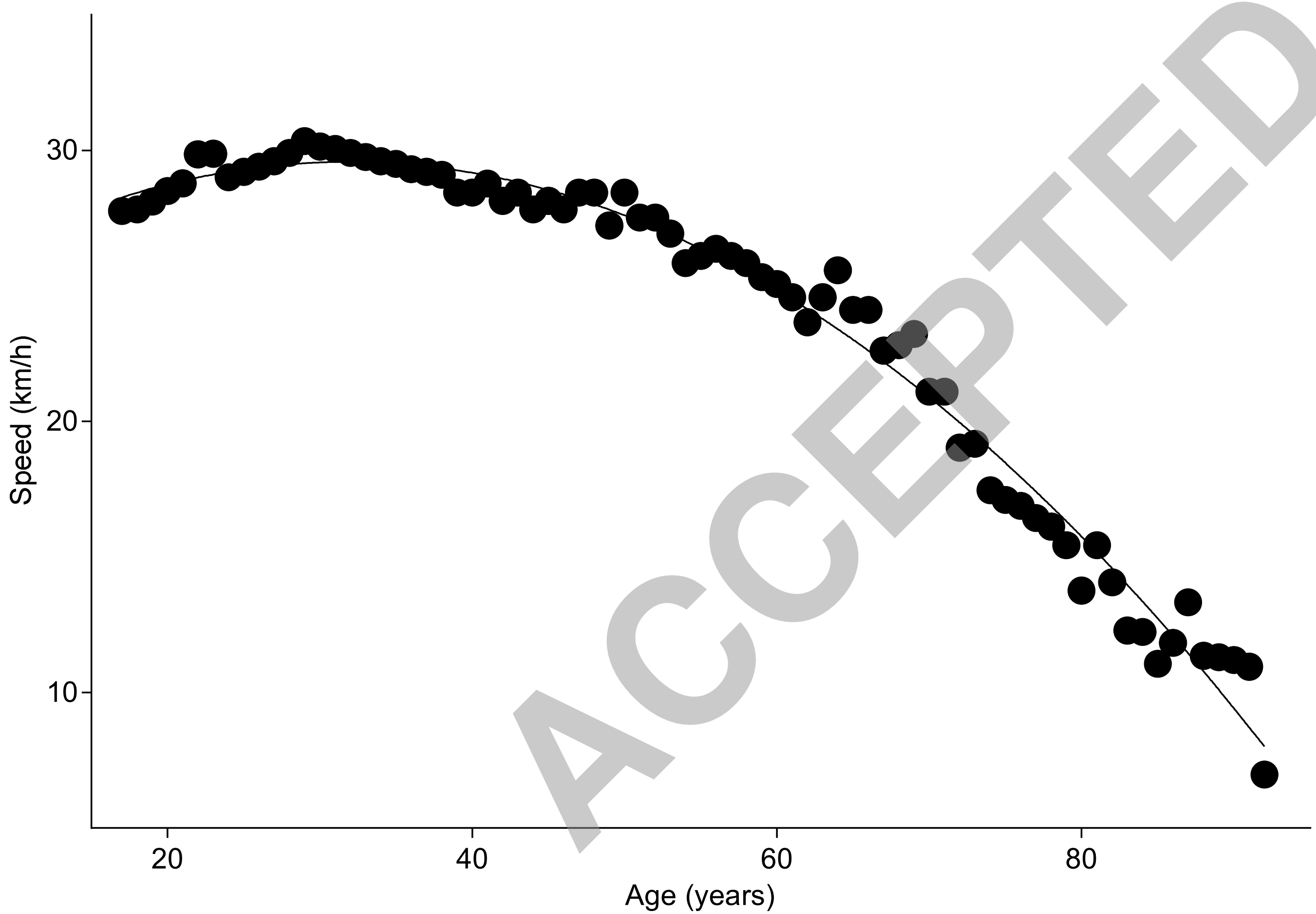


Figure 5

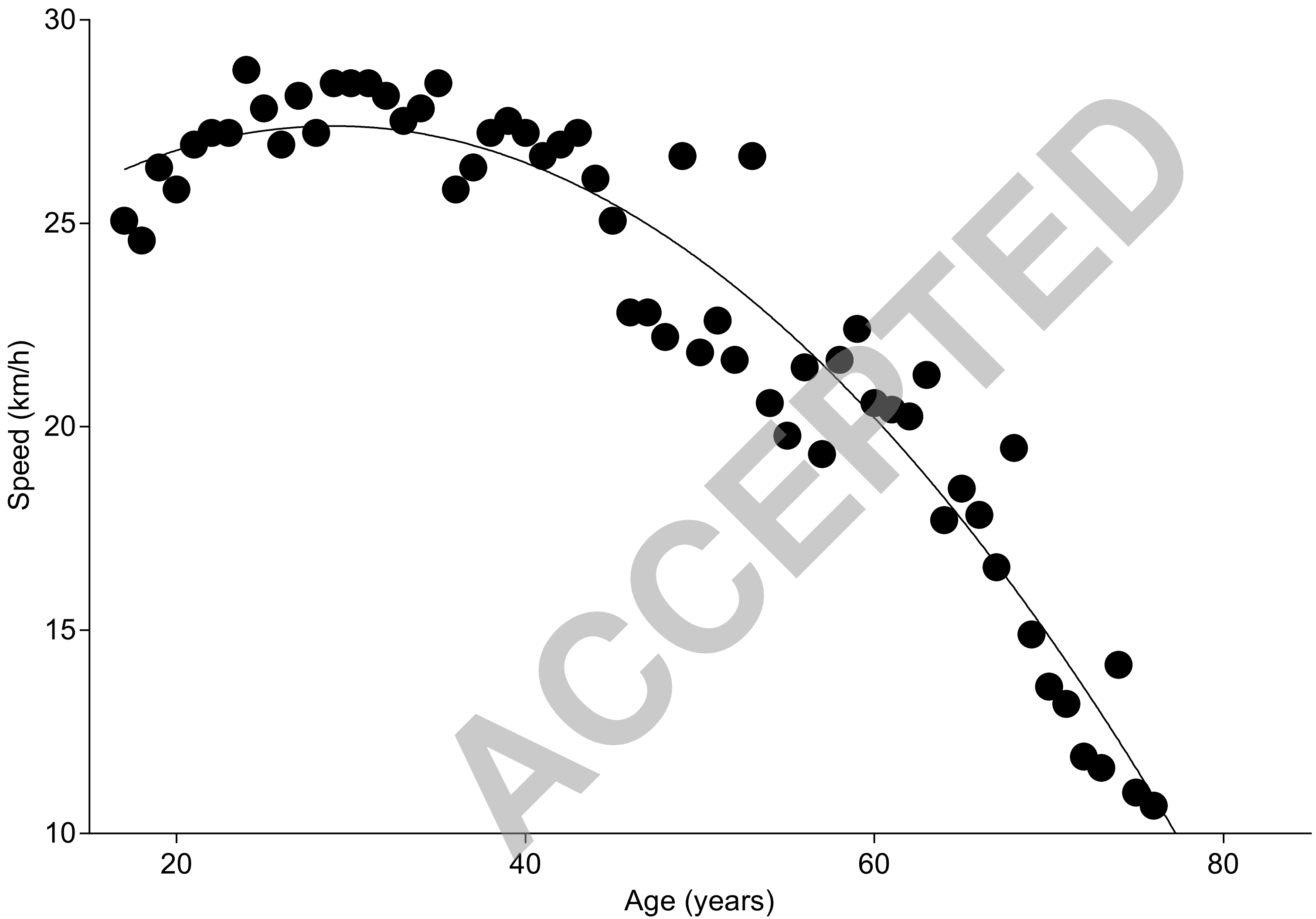
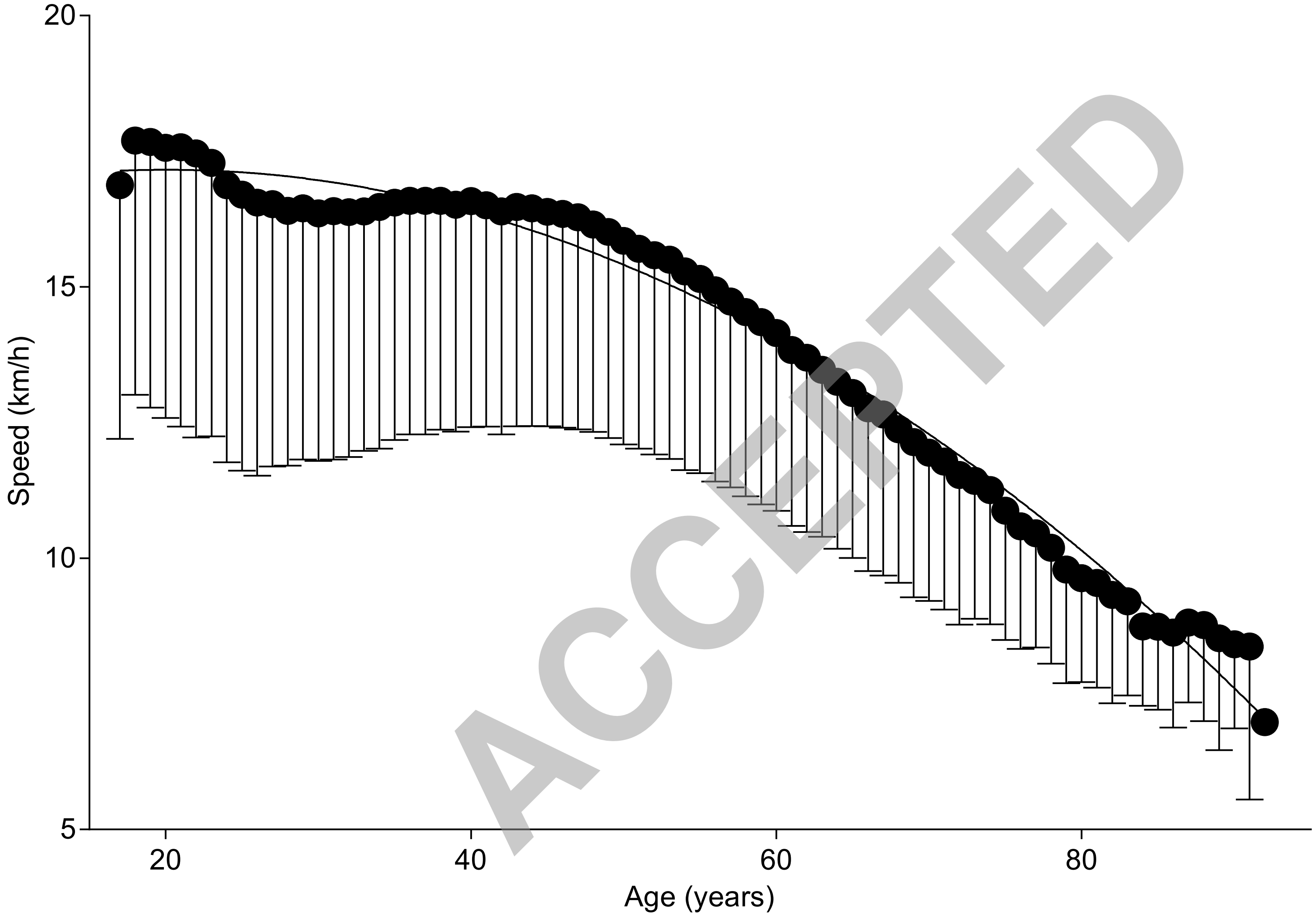


Figure 6



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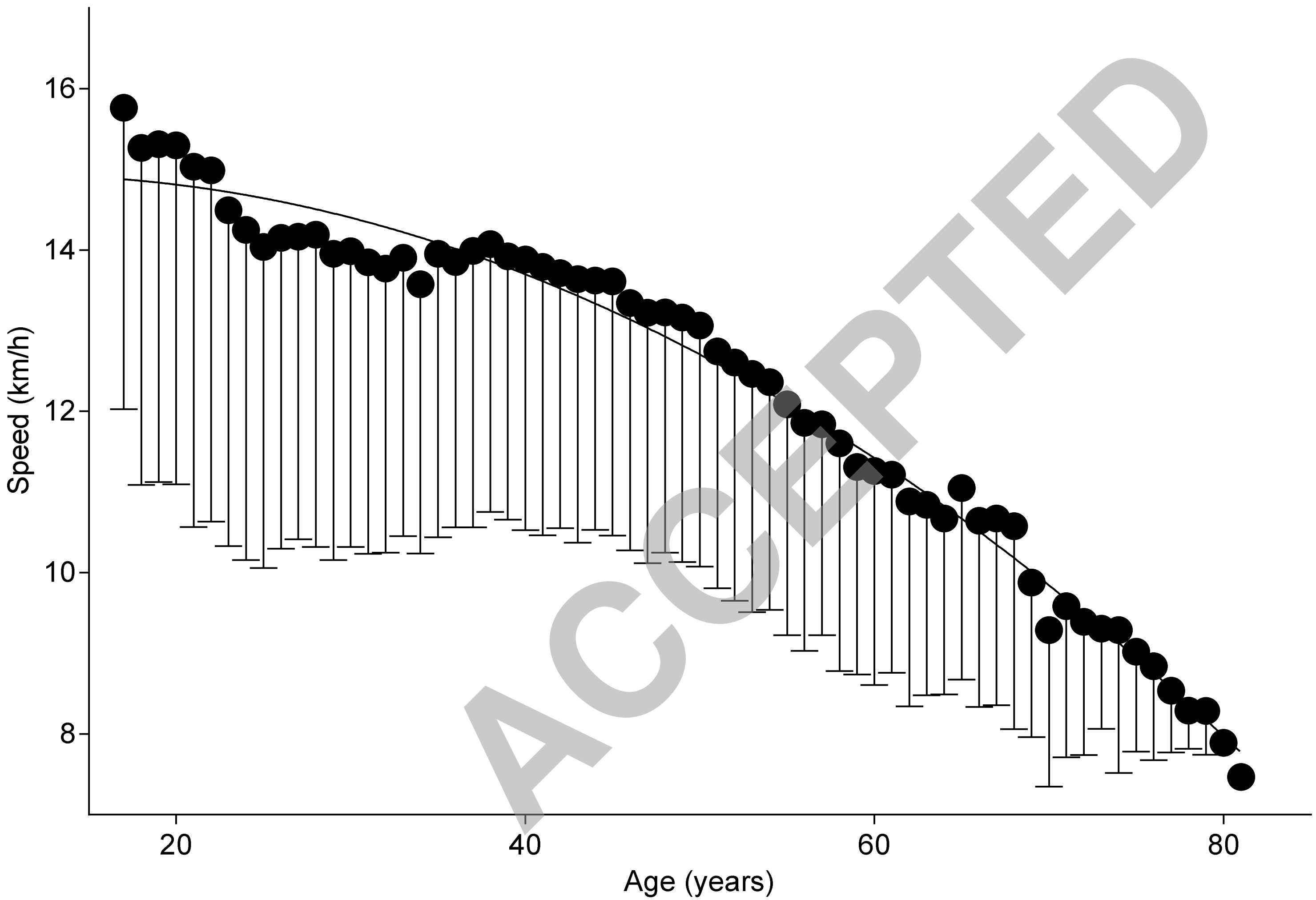

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424 **Figure 8**